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ARTIFICIAL INTELLIGENCE'S ROLE IN ADVANCING THE NATIONAL IMAGERY AND MAPPING AGENCY (NIMA)

BY

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ABSTRACT

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Artificial Intelligence (AI) has the potential within the next 30 years to make major impacts on the imagery and geospatial intelligence tradecrafts and the U.S. Imagery and Geospatial Systems (USIGS) infrastructure. This paper seeks to determine whether NIMA is positioning the agency and USIGS community to take advantage of AI in its mission areas, how well are they doing, and where might they improve? This will be assessed through an examination of current relevant AI technologies, ongoing NIMA technologies and NIMA research and development (R&D) programs. Findings show that NIMA has been involved in AI related areas, especially over the past three years and are expanding those programs in their transformation efforts. However, most of their technology is focused on near term. Recent programs are looking at the mid-to-long term technologies that leverage off of core AI technologies. While there are programs for R&D in these far horizon areas, current funding profiles are limited and do not match the intent or purpose of the research effort. There is also an investment shortfall in the infrastructure to make the new technologies work. Artificial Intelligence R&D programs have the potential to revolutionize NIMA's industry and disciplines; it also has a crucial global role in advancing the use of imagery and geospatial products, data and services.

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PREFACE

We recognize that the future, while dynamic and problematic, holds many significant challenges for the National Imagery and Mapping Agency's (NIMA) strategic leadership team. As the proponent of imagery and geospatial intelligence (integrated geospatial and imagery intelligence) for the USIGS community, one of the most significant issues is whether or not NIMA's R&D efforts are proportionally and appropriately focused on the utilization of new technologies that will radically change the way the agency does business throughout the 21st Century. Is the agency leading or taking advantage of efforts in the fields of Artificial Intelligence (AI) and is it positioning itself to better shape and advance the intelligence and geospatial communities? To meet this challenge, NIMA must encourage innovative techniques and solutions to difficult and complex geospatial intelligence needs and leverage off of technological advances in AI made in the private sector, the DoD, and the Intelligence Community (IC) at large. Senior leadership should focus through sound strategic orientation. In addition, they must plan and budget for R&D to make sound calculated risks in the areas of AI where it is most suited to the geospatial and imagery analysis professions and national security role both in the short and long term. Special acknowledgement is given to the men and women belonging to the NIMA InnoVision Directorate involved with the Futures Division and the Advanced R&D Division, namely significant contributions by Ms. Becky Aiken and Mr. Mike Gilbert. They provided expertise and invaluable insight into NIMA's current technology programs, without which this paper would have no authentic baseline and professional grounding.

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ARTIFICIAL INTELLIGENCE'S ROLE IN ADVANCING THE NATIONAL IMAGERY AND MAPPING AGENCY

Artificial Intelligence (AI) has the potential within the next 30 years to make major impacts on the imagery and geospatial intelligence (integrated geospatial and imagery intelligence) tradecrafts and the U.S. Imagery and Geospatial Systems (USIGS) infrastructure. This paper seeks to determine, through an examination of current relevant AI technologies and ongoing NIMA technologies and R&D programs, whether NIMA is positioning the agency and USIGS community to take advantage of AI in these mission areas. If so, how well are they doing and where might they improve? The criteria for assessment will include an examination of the following: US National and DoD strategic policy and planning guidance; the NIMA mission, strategic plan and mandated commission findings; an overview of current AI technologies that relate to imagery and NIMA mission areas (subdivided into overall scientific research disciplines and DoD focus efforts); and an examination of current NIMA R&D programs with a risk/tradeoff assessment. The conclusion will assess the degree to which NIMA R&D programs include AI technologies and will include recommendations about Artificial Intelligence R&D programs and funding that having the greatest potential to revolutionize the imagery and geospatial intelligence industry and disciplines.

Artificial intelligence, or AI, is a fast-moving area of science. The ultimate purpose is to create computers that think or perform cognitive tasks. Scientists are working on machines that have the ability to look after themselves and make decisions that humans make now.

> The term artificial intelligence was used in the 1960s by researcher Marvin Minsky, who described it as the science of making machines do things that would require intelligence if done by humans. Minsky thought that AI machines could do things such as learning, recognizing patterns, translating languages, playing games, exploring on land and in water, and solving problems. And should be able to size up a situation and choose a sensible action....that if wrong, could learn from its mistakes to try again in a different way. [1]

Humans do many things instinctively, without given much thought to them. No one has yet discovered quite how the human mind works. This is one of the problems AI scientists are trying to solve. Like humans, robots and AI instruments need to know what is going on around them. Sensors do that job, many times detecting better than humans.

Much of AI deals with the way the human brain works. AI researchers use neural (nerve) networks to reproduce in a machine some of the functions of a human brain – called neuroscience. Currently, most AI technology is no more intelligent than simple insects.

Researchers are working on neural networks that 'evolve', with the goal of developing systems (machine learning) that allow brain-like functions to evolve.

From the beginning of advanced computer developments, there has been a research track that concentrates on getting computers to ``reason" like humans. Intelligent behaviors are modeled as the result of a system searching through a set of states, or descriptions of itself and its environment, until it finds a state that solves the problem at hand.[2] Although this is a more basic AI method, progress has been made on this research track in the areas of knowledge representation, theorem proving, game playing, expert systems, resource management, scheduling, and machine learning.[3] In the early seventies a new research area within AI emerged, the *perception* track, which

> emphasized reproduction of the aspects of intelligence that allow a system to perceive and manipulate its environment. Work in this area began by building on earlier research in pattern recognition, control theory, and human and animal physiology. The goal of many projects in this area is to design systems that do not just numerically process a sensory signal but also apply high-level knowledge about the environment to constrain the identification or manipulation of the objects generating the signal. Topics within this track include computer vision, speech recognition, auditory scene analysis, robotic path-planning and kinematics, and robot design.[4]

Many of NIMA's major **challenges** today are driven by technology shortfalls in critical business operations areas such as bandwidth, storage, processing speed, multi-level security requirements and resource constraints. Furthermore, many of the intelligence and geospatial related data and production needs are manpower intensive and inadequately resourced. Therefore NIMA's strategic orientation must address all of these problem areas while planning for an adequate scope and scale of change for the future.

Artificial Intelligence R&D programs may provide the **solution** to NIMA's ability to 'guarantee the information edge' to its customers and the nation. AI technologies have the potential to revolutionize NIMA's industry and disciplines; they also could play a crucial global role in advancing the use of geospatial intelligence products, data and services over the next 30 years. Many of these AI technologies have direct applicability to NIMA mission areas and the imagery and geospatial intelligence disciplines. USIGS mission functions that AI has the capability to impact include: (1) the freeing up of analytic resources in manpower intensive tasks, (2) the use of computers to scan large volumes of data to identify changes or items of interest, (3) the automation of many manual processes and tasks, (4) the capture of methodologies and expertise for training and advancing geospatial intelligence tradecrafts, and (5) the infusion of source data without human intervention, to name a few. These inexorable

advances may eventually result in "computers exceeding the memory capacity and computational ability of the human brain and may be achieved by 2020, with human attributes not far behind – possibly by 2030 information may be fed straight into our brains along direct neural pathways."[5]

US NATIONAL AND DOD STRATEGIC POLICY AND PLANNING GUIDANCE

Why is research in AI relevant to the nation and the Department of Defense (DoD)? As an integral part of the Intelligence Community (IC) in support of both national and DoD requirements, NIMA's mission requires its workforce to make informed, timely decisions and be able to dominate across the full spectrum of military operations, in peace and in wartime. As stated in Joint Vision (JV) 2020, the goal of full spectrum dominance requires the continuous infusion of new technology evolved around the hub of information superiority and precision engagement. As key enablers, they provide the joint force a competitive advantage in the form of superior knowledge to shape and respond to enemy threats.[6] JV 2020 also identifies technological innovation as a vital component – "a combination of new 'things' with new 'ways' to carry out tasks. In reality it may result from fielding completely new things, or the imaginative recombination of old things in new ways, or something in between."[7] Knowledge and new technologies that facilitate or augment this are the key enablers. More pointedly, the need for Dominant Battlespace Knowledge of disposition and intentions of the enemy are crucial. "Advanced sensor and information fusion will be expected to provide near-perfect, real time discrimination between targets and non-targets on the battlefield of the future."[8] Artificial Intelligence technologies will be key to solving this knowledge problem.

For NIMA to assess whether their new 'Statement of Strategic Intent' is consistent with the National Security Planning Guidance, we must examine the ends, ways, and means as directed by national and DoD policy, plans and guidance. Although there is no current National Security Strategy (NSS), the previous administration's guidance states that the DoD must be able to "respond to threats and crises to enable the nation to shape and respond at home and abroad against a full spectrum of threats and crises that may arise… for the end goal of shaping the international security environment in ways that protect and promote US interests"[9] – the <u>End State</u>. NIMA's function as geospatial intelligence information provider is crucial and integral to that mission.

The 2001 Quadrennial Defense Review best articulates <u>how</u> (ways) the DoD will transform to maximize the operational effectiveness of the most valuable but most scare resource – people. It states that this should be done through a combination of technologies,

innovative concepts, and organizational arrangements. Of particular note are the following directives: "to increase their situational knowledge and ability to locate and track targets; capitalize on robotics and unmanned systems; and enable forces to rapidly adapt to emerging threats and exploit technological or operational breakthroughs through continuous research, development and experimentation."[10] NIMA seeks to optimize the effectiveness of its unique expertise pool to assist scientists and researchers in gaining and understanding their methodologies and knowledge toward this effort. NIMA also manages and trains the nation's geospatial intelligence professionals and sets policy and standards for these disciplines.

Both the Director of Central Intelligence (DCI) and Assistant Secretary of Defense (ASD) (C3I) are charged with what resources and programs (means) are available and will be used at national, operational and tactical levels to achieve intelligence superiority for decision makers and users of intelligence, from conception to end of useful life. NIMA manages a robust set of programs spanning the imagery tasking and requirements, imagery intelligence, and geospatial spectrum. USIGS and Tasking, Processing, Exploitation, and Dissemination (TPED) are the mechanisms NIMA uses to manage and disseminate this time-sensitive information, products, and services. Severe impediments to the advancement and transformation of this architecture and infrastructure would be detrimental to the accomplishment of national and US Defense strategy goals and objectives. The need for extensive R&D and technological advancement has been highlighted as a need from the National Security Council (NSC), the Secretary of Defense (SECDEF), the DCI, and the Director/NIMA. A crucial question is whether NIMA is adequately resourcing and executing programs that will best meet these challenges.

NIMA MISSION, MANDATED COMMISSION FINDINGS, AND NIMA STRATEGIC INTENT

As both a national intelligence and DoD combat support agency, NIMA's mission and vision is to provide timely, relevant, and accurate geospatial intelligence in support of national security objectives, the nation's policy makers, government agencies, civil users, and the nation's military forces. Their vision is to "Know the Earth...Show the Way."[11] As a member of the Intelligence Community (IC), it is the single entity upon which the U.S. Government relies on to comprehensively manage the previously separate disciplines of imagery and mapping. NIMA is charged with the management of all imagery and geospatial intelligence professions. This includes the infrastructure necessary to provide timely and accurate products and data to advance national decision making and contribute to the high state of operational readiness for America's military forces. Also, NIMA has oversight of USIGS – the extensive network of systems used by the DoD and the IC that share and exploit imagery, imagery intelligence, and

geospatial information - and its interfaces from and into other national, DoD, and international/multi-national organizations involved in geospatial and imagery related products and services.

Reshaping and influencing NIMA's strategic direction, the NIMA Commission of 2001 conducted a thorough examination of NIMA's business processes. The findings recommended some significant changes that NIMA has incorporated into their strategic plans and programs. These included:

> resource changes for the Director of NIMA to request through the DCI and Congress to duly authorize and appropriate, an increment to the NIMA Program for advanced research and development (R&D); the position of Chief Technology Officer should be created and a top-notch individual found to encumber it; and for multi-Intelligence (Multi-INT) TPED – The DDCI/CM and ASD (C3I) shall jointly determine the extent and pace of convergence toward a multi-INT TPED This would include the integration of other intelligence sources such as SIGINT and MASINT.[12]

In the TPED concept, "exploitation" is the most abstract of the concepts and comprises "all those value-added activities that transform imagery into intelligence or, more generally, the link in the chain that transforms *information* into *knowledge*."[13] It is this function that over the long haul will be most challenging for AI since it deals with the principles and processes cognizant within the human brain. The NIMA Commission was especially concerned about the inadequate level of *ADVANCED* research and development efforts on and behalf of NIMA that hold the future of TPED hostage. Most notably, technology was identified as necessary for interpretation of hyperspectral imaging, ultraspectral imaging, synthetic aperture radar (SAR), atmospheric distortion, denial and deception, ground and air moving target indicators (GMTI and AMTI) technology, all of which exceed natural human experience and knowledge. Speed (faster cycle-times) was another identified area needing extensive R&D focus to fulfill JV 2020 requirements of sensor-to-shooter, sensor-to-seeker, and Common Operational Picture (COP) information to the military user. Resource funding and technical expertise shortfalls were expressly identified throughout the report indicating that NIMA would not be successful with TPED and/or USIGS needs without additional funding and expertise from the DCI and ASD(C3I) (augmented by Congress) as well as public and private corporation high-technology partnering efforts.

To address many of the challenges and issues outlined by the NIMA Commission, NIMA's Statement of Strategic Intent calls for a transformation of the organization and mission imperatives to execute requirements across the temporal spectrum to include NOW, NEXT, and

AFTER-NEXT simultaneously. Of the ten 'strategic goals' several apply directly to future technology investments and programs to address NIMA's challenges:

1. *We MUST champion and complete a complex set of major investments, to move us to the NEXT level of the National System for Geospatial Intelligence (NSGI).*
2. *We MUST forge the AFTER-NEXT environment by constantly driving future technical trends and applying them to operational needs, inserting technology rapidly, and providing relevant Geospatial Intelligence, services and solutions.* This is especially relevant to the insertion of advanced technology developments into the NSGI.
3. *Continue the transformation of our business model by using best practices to enhance our position as the premier geospatial intelligence provider.* NIMA is active in three elements of the common relevant operating picture (CROP) (a) auto updates of databases (b) visualization – layering of data, meta data, geospatial underpinnings, fixed spatial elements, simplification of data into visual means, literal data, threat icons, use of flickering lights, mission planning data (simulators) flying terrain, vertical obstructions, and (c) data in terms of reports or internet with their cause and effect relationships, and correlation between relations/activities and unseen data.
4. *Championing Multi-Intelligence collaboration.* The IC is sponsoring several R&D initiatives focused on multi-agency intelligence processes, especially tasking and requirements generation.
5. *Transform our infrastructure.* Because of technology advances (specifically in the fields of advanced computers), processing and exploitation have merged as functions where the analyst/exploiter does both, especially in the realm of taking images and piecing them together to provide a synoptic view. Also, exploitation processes are often serendipitous and therefore not programmable since issues and responsiveness required changes too quickly in response to world issues/situations. However, we have under-invested on the infrastructure; therefore, this issue must be addressed before new technologies can be inserted. In the area of dissemination, the demarcation of bandwidth to JTF level and services is still very pronounced.[14]

Figure 1 Demonstrates the framework that NIMA's InnoVision Directorate is using to link together enabling and advanced technologies to meet NIMA Strategic Intent.[15]

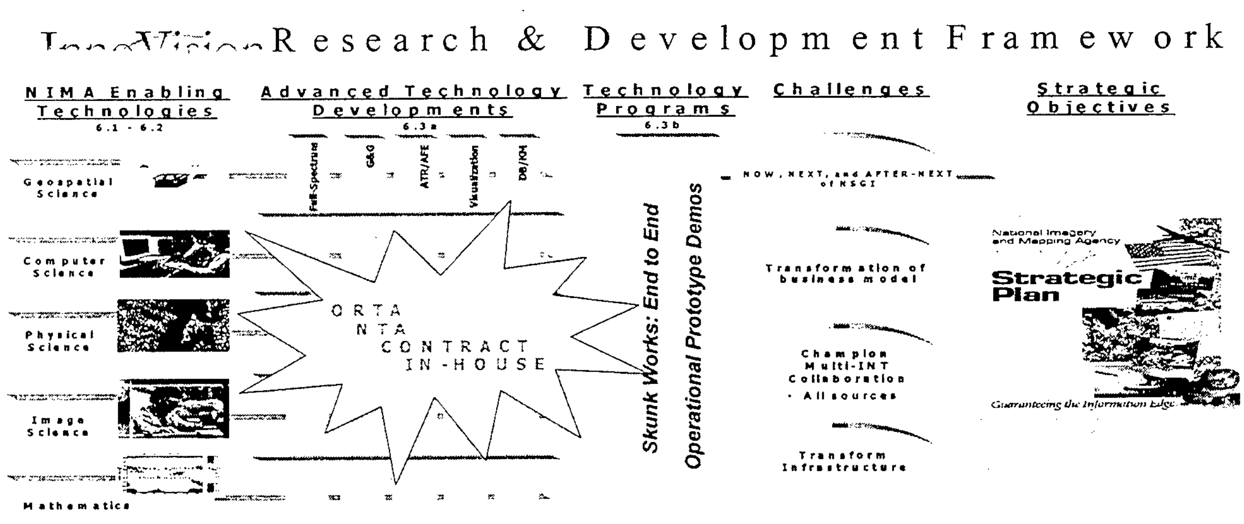

FIGURE 1 R&D EFFORTS AGAINST NIMA STRATEGIC INTENT

Another primary factor affecting NIMA's strategic plan is the findings from the NIMA Commission, which stated shortfalls in NIMA's Information and Science and Technologies capabilities. The following figure, taken from a NIMA R&D Overview Presentation briefing by the Deputy Director of NIMA's InnoVision Office, Dr. Robert Laurine, shows the direction that NIMA is taking in its R&D programs to try and address some of these deficits.[16]

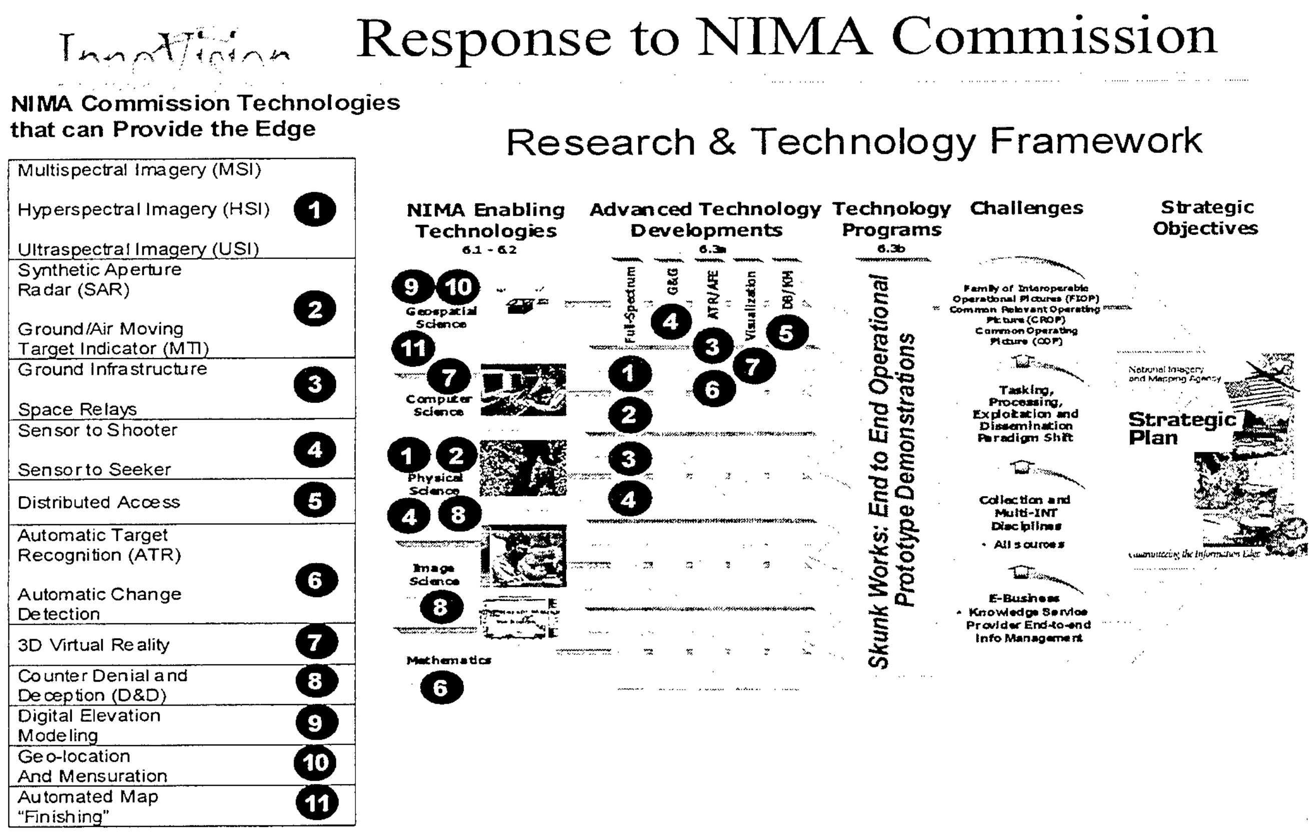

FIGURE 2: R&D RESPONSES TO NIMA COMMISSION

Now that NIMA's long term objectives have been presented, we must examine overall AI and other advanced technologies that are under development within the scientific and DoD communities and have possible utility to NIMA mission areas.

CURRENT AI TECHNOLOGIES

OVERVIEW OF SCIENTIFIC RESEARCH DISCIPLINES

Internationally AI is involved in several related fields having the potential to revolutionize human quality of life and business processes in terms of efficiency and effectiveness as we know it through the fields of *neuroscience, computational vision, machine learning, knowledge-*

based systems, intelligence agents, expert systems, and intelligence computer-aided instruction (ICAI). New technologies involved with knowledge management and computers will also significantly change or enhance the way the US government and the world processes and exchanges information. The field of AI is really about "inventing machines that will help people in a variety of ways, by giving machines some of the sophisticated capabilities that humans have, such as the ability to understand spoken words, or interpret images, or to learn from experience."[17] Although the machines do not resemble people, they can be useful by improving and assisting in efficiency and effectiveness, complementing rather than replacing humans.

Neuroscience has proven one of the greater challenges to the AI community. It has great potential in the private and commercial sectors as well as for the imagery and geospatial fields, and therefore will continue to be developed for a multitude of applications. Neuroscience seeks to mimic the human brain or neural network structures. As such it uses parallel and distributed computing, is self-organizing, utilizes distributed knowledge representation, requires learning as a fundamental principal, and uses pattern recognition and optimization techniques. Most of the successes have been realized in biomedical imaging areas to date.[18] Many major technology centers, such as MIT, have been focusing on both neuroscience and computer technologies in their biotechnology programs. Large increases in funding for these programs present a 'calculated risk' to position the school to 'predict the next generation of intellectual revolutions' and key their future.[19]

Computational Vision seeks to understand the visual information represented in images and image sequences. That is, the computer must be able to view an image and report on the contents in a useful manner, where utility may be measured by specific task or by the standards of human perception.

> Research in the field ranges from practical industrial vision applications to the design and construction of robotic vision sensors such as stereo heads to attempts to understand how the human brain processes and uses visual information. As a result, there are many sub-areas of research within computational vision, including edge detection, segmentation, texture analysis, color perception, stereo tracking, perceptual organization, object recognition, active and attentive vision, sensor design, motion analysis, event perception and learning.[20]

Digital filtering, motion analysis, image registration and segmentation, and model matching schemes are areas where progress has been made in the field of computer vision and have much utility in NIMA and military mission areas. Work in the area of knowledge-based vision incorporates methods from the field of AI in order to "focus on the influence of context on scene understanding, the role of high level knowledge, and appropriate knowledge

representations for visual tasks."[21] Recent studies reveal that as Intelligence Agents acquire knowledge through sensors, the use of context and knowledge basic reasoning tasks can be performed. That is, knowledge and context can influence visual interpretations of a scene, resulting in fewer false alarms.[22] Some impressive successes have been made but there are a large number of open problems in several of the fields mentioned earlier which will probably not be solved in the near term.

Machine Learning and statistical pattern recognition include the use of probability theory, Bayesian methods, graphical models, learning theory and mean field methods from physics. Machine learning is an extremely important area for AI in that it can be viewed as a search of concept descriptions, looking for a best match and understanding of the current situation. Learning is closely related to general problem solving abilities and requires a vast amount of knowledge and some analytical reasoning capability.[23] Learning can take the form of 'discovery' or 'analogy' and is key to enabled learning in autonomous systems. Some new directions include the development of synthetic intelligence algorithms that are useful for practical tasks to gain insight into how the brain performs supervised and unsupervised learning. It also captures how it represents information in the neural code. MIT has been involved in research for DARPA on multi-resolution SAR-based ATR and analysis through the integration of sensor physics, statistical analysis and modeling in Imagery Understanding (IU) methods and techniques. This is targeted against problems of manmade and natural scatters and within the field of Image Understanding methods and techniques.[24]

Knowledge-based Systems/Knowledge Representation (KR) is the study of how to impart knowledge of what every human being knows about the world to a computer. The challenge is our ability to describe the world in such a way that a computer would be able to draw appropriate conclusions about the world. Once knowledge is represented, the computer must be able to select the correct behavioral strategy often in an ambiguous or uncertain situation. Minsky, the founder of the MIT AI Lab and man often referred to as the "the father of artificial intelligence", stated that "computers need to develop common sense, which incidentally also means that they need to be equipped with certain basic emotions." [25] His new book, The Emotion Machine, explores the idea that emotions are "simply different ways of thinking, and that machines, to be effective, need to find various methods of considering problems to solve them efficiently. Most computers now have at best one or two ways to resolve problems."[26] He also states that this common sense reasoning may be possible in the next 10-15 years. This would be extremely useful to NIMA by capturing analytic knowledge at varying depths for mentoring, training, and ensuring resident knowledge remains after the individual departs which

seems to be critical as NIMA's workforce ages and retires. At the least, it could identify and prioritize issues or anomalies that humans could investigate.

Knowledge Management (KM) includes the collecting of data, and by recognizing and understanding relationships and patterns, turning it into useable, accessible information and valuable knowledge. This is a broad field using new technologies to enable organizations to harness, manage, and utilize their knowledge resources more effectively, regardless of form by tracking and transferring knowledge. Database management systems, data warehouses, data cleansers, and data mining technologies fall within this category.[27] For instance, data mining utilizes search capabilities of machines to become predictive tools by putting crucial, mission specific data to work for humans. These are highly applicable in the short and mid term to assist NIMA in her information edge mission areas especially in trend analysis, targeting and crisis management responses.

Intelligence Agents exceed the field of KM and include software and advanced communications tools that help leaders make critical decisions by filtering incoming sensor and communications information and suggesting actions to be taken. Intelligence and adaptive interfaces (agents) could be used to

> standardize data from many diverse sources before it is combined into a common awareness picture. Network agents can be employed to ensure the massive communications infrastructure that will be required to move awareness data is kept us and running. Various taskbots could be used to combine data to build the battlefield picture. These agents could notify human operators of problems that require their intervention.[28]

Awareness implies that the user is seeing more than just graphic or symbolic interfaces merging imagery, geospatial, and positional data into a virtual reality model with real time data.

Expert Systems are computer programs with "a knowledge base of expertise capable of reasoning at the level of an expert in some given domain; a computer program that can perform at, or near, the level of a human expert."[29] Some experts tend to differentiate between 'expert systems' and 'knowledge systems' by defining the later as one or more small systems developed by means of AI using expert knowledge to attain high levels of performance in a narrow problem area. Expert systems represent a potential vital technology that could balance the disproportionate relation between voluminous data relative to manpower constraints in the form of numbers of analysts to exploit or analyze it. "Expert systems use template-like programmed situations or terrain to perform a controlled search and discover. Expert systems are capable of handling situations that they have been programmed to handle."[30] Although many of the situations and information analysts handle are intuitive and therefore are inductive

in nature, some situations will lend themselves to these systems to burden share some of the manpower intensive tasks. Expert systems will be needed to capture expertise of the imagery, geospatial, and collection management professionals as the DoD workforce continues to downsize and retire in the very near future.

Intelligence Computer-Aided Instruction (ICAI) systems are intended to augment or replace human instructors. They are labeled as knowledge communication systems. Although ICAI systems rely on a variety of important disciplines, AI addresses many of the real difficulties for the system. "These include schemes for knowledge representation, reasoning about knowledge (of different types), and ideas on how to communicate knowledge to a user."[31] An ICAI system would attempt to interpret student behavior over time to decipher the root cause of misunderstandings or where the student is having problems understanding. ICAI systems have several primary components.

> First they require problem solving expertise to represent the knowledge that the model must communicate to a student. Most ICAI systems also rely on a student-model component ... intended to represent a model of what the student knows at any point in time so that the student's knowledge can be contrasted with what a typical and/or expert student might know. Also, ICAI systems rely on tutoring components that include pedagogical information to specify how knowledge should be imparted to the student.[32]

With the projected retirements and continued select downsizing projected within NIMA over the next 5-10 years, the ability to impart expert knowledge into NIMA training programs and instructional systems would be invaluable in developing and maintaining a high-caliber workforce. It would also serve to ensure quality and high standards in many of the various diverse tradecrafts that may be most impacted and/or subject to downsizing. ICAI could capture a lifetime of expertise from senior technical experts that could be used to quickly train-up large numbers of individuals in a crisis situation.

AI and computing are being inextricably linked by major commercial software giants. Bill Gates, Chairman and Chief Software Architect for Microsoft Corp, in 2001 delivered a keynote presentation at the International Joint Conference on AI, stating that AI is "the next frontier in computing and usability," and that "Microsoft is focusing more on research in this field than ever before...building technologies that will enable computer to see, listen, speak and learn, so people can interact with them as naturally as they interact with their friends."[33] Microsoft's research division is "addressing both principles and applications of AI, and includes research teams dedicated to automated decision-making, knowledge representation, information retrieval and search, machine learning and data mining, natural language, speech and handwriting

recognition, and vision."[34] New small innovative technologies companies are sprouting up to take care of niche needs centered on web and business intranets. TSN, a new Arizona based company, has announced a search engine development called Source Network's natural language search portal (NLSP) that implements decisions like human thought processes. Through neural network algorithms and AI, the software search engine uses natural language processing to search and retrieve relevant information, quickly and accurately.[35] This NLSP provides a tremendous capability for intelligence and geospatial analysts, especially in the fields of Open Source Intelligence (OSINT) infusion into intelligence and geospatial databases, crisis management, and trend analysis.

DOD FOCUS EFFORTS

Within the DoD there are targeted AI areas that DARPA is investing its R&D funds into advanced technology programs or Advanced Concept Technology Demonstrations (ACTD). These are intended to develop the seed technology for sensors and communications, exploitation, and information integration that may have direct impacts on USIGS imagery and geospatial disciplines and infrastructures. These include specialized ACTD programs, Automatic Target Recognition (ATR), Image Understanding (IU), Unmanned Aerial Vehicles, nano-technology, intelligence agents and expert systems, to name a few.

One ACTD program, *Semi-Automated IMINT Processing (SAIP)*, is being developed to provide an integrated suite of tools for the tactical field commander's battlefield awareness from high-volume imagery intelligence (IMINT). Source data is derived from manned and emerging unmanned sensor platforms and includes SAR and electro-optical sensors against wide area search and point target surveillance. The goals include aid to imagery analyst's effectiveness and efficiency through cueing of targets or site change detection, with an accuracy rate of great than 90% and false alarm rate less than one event for every hundred square kilometers being assessed. The system will also be compliant with USIGS architecture and standards.[36]

DARPA is the leader in *ATR-related R&D programs*; however, the services also have their own programs. The aim of ATR technology is to assist military commanders to find and kill targets within seconds and utilizes Expert Systems, Image Understanding, and Computer Vision AI techniques. More than just acquiring and identifying targets, it takes information from sensors, processes it and turns it into useful targeting data without the fog of war. The primary objective of ATR developers is to reduce the workload of human operators from data overload. It is predicted that within the next two years "it will be possible to have real-time ATR on a laptop computer."[37]

DARPA Special Project Office is sponsoring the *Moving and Stationary Target Acquisition and Recognition (MSTAR) Program*, centered on the development, integration and evaluation of an advanced ATR system targeting high-performance identification of tactical and strategic target signatures with synthetic aperture radar (SAR) imagery for dominant battlefield awareness. These are critical to the development of high model-based ATR performance, screening large areas of surveillance imagery for possible targets, and final target recognition. Three MSTAR modules include Feature Prediction, Feature Extraction and Feature Matching.[38]

For the Army, ATR is being explored for the Comanche helicopter. An advanced second-generation forward-looking infrared sensor, the air-land enhanced reconnaissance and targeting system (ALERT), will perform 'rapid search-on-the-move' for the detection of static and moving targets. It scans 20 times faster than a human operator. Along this line, the Army has unveiled an advanced 'thinking' cockpit management system, the Rotorcraft Pilot's Associate, which encompasses an integrated suite of sensors and displays designed to revolutionize the way combat helicopter pilots will fly. It includes data input from "the Tactical Receiver Intelligence Exchange System, Joint Surveillance and Target Attack Radar System, the Tactical Operations Center, Aircraft Survivability Equipment, an ATR system based on forward looking infra-red and radar sensors, and the Battlefield Combat Identification System." [39]

Many of DARPA's *Image Understanding (IU) programs* are linked to ATR objectives as well as imagery and geospatial exploitation analytical tools. The Quick-Look concept is part of the *RADIUS Experimental Program* that seeks to prioritize imagery for exploitation for imagery analysts. This would be done through profiles of sites/targets and change detection algorithms that indicate changes from the norm. Only the images with notable changes would be highlighted to the analysts for further exploitation.[40] Another part of RADIUS experiment involves monitoring scenarios for air, industrial, and ground related facilities. This experiment focuses on actions that an imagery analyst would perform while exploiting imagery of a facility to assist in the development of IU research. The intent is to assist analysts by prioritizing imagery for exploitation, count objects of interest, identify unusual activity and note changes in activity and facilities.[41] Many of the other programs and experiments involve expert systems, computer vision, intelligence agents for motion imagery for UAVs, imagery exploitation and ATR (IMEX/ATR) and automatic population of geospatial databases (APGD).[42]

UAVs use many forms of AI to complete their missions. They use sensors to spot objects 30cm across and can map an area of about 40,000 square miles in 24 hours, record events, and allow human controllers on the ground to see through video screens. Multiple sensor packages include Electric Optical Imagery (EOI), radar (SAR, FTI, MTI and an improved

multi-platform radar), and infrared (IR) imagery as well as signals intelligence capabilities. While the aircraft is in flight and sensors are collecting, video is passed back to human ground controllers in near-real time. The Air Force's RQ-4A Global Hawk, is a high altitude endurance UAV capable of a maximum endurance of 42 hours. [43]

The Army Tactical UAV, Shadow 200 system, consisting of a tactical UAV radar generating both SAR and MTI imagery, will be able to land automatically without human intervention.[44] The Army and DARPA are also kicking off the first phase of testing in the joint Unmanned Combat Armed Rotorcraft (UCAR) program. The objective of this program, previously known as the robotic rotary wingman, is to "determine the technical feasibility of an armed vertical takeoff and landing (VTOL) UAV to effectively and affordably prosecute strike missions within the Army's emerging Objective Force warfighting concepts and systems architecture." The platform will support manned platforms (Comanche scout) as an element of a manned-unmanned systems team.[45]

The Navy is looking at a vertical take-off and landing UAV (VTUAV) that could operate from a shipboard helicopter pad. The Fire Scout VTUAV includes GPS navigation, a laser-designator and an EO/IR sensor. The Marines are funding the Dragon Drone, which includes a 32bit unified autopilot, an Inframetrics MILCAM-XP thermal imager, an ALST laser rangefinder and a new ground station. [46] This drone is also being used in advanced warfighting experiments. The DoD is investigating quantum leaps toward both micro-UAVs and large but stealthy air vehicles which will leverage off of AI technology advancements.

The DARPA sponsored *"MATISSE" project* will develop an "information system that will use microelectromechanical systems (MEMS) research centers, fabrication sites, and specialized equipment with advanced computing, resource management and storage resources via a very high speed nationwide network, the Supernet."[47] The objectives are to implement and test the application software to enable the platforms to operate effectively in the SuperNet environment, and develop software for analyzing and visualizing raw imagery data generated by test platforms. "The features include filters for image enhancement and feature recognition, volume rendering of multi-dimensional imagers, motion estimation algorithms for quantifying mechanical motion and flow, and an algorithm for comparing actual structures and initial designs."[48] As well as applications to the DoD, this AI field is extremely relevant to the private sector, especially in the fields of health, aeronautics and space, commerce, and energy.

In the field of *Intelligence Agents*, the DoD is developing battlefield management software and advanced communications tools that will help future commanders make critical decisions, especially as the military moves toward more data-centric warfare. The Marine

Corps are concentrated on the *Integrated Marine Multi-Agent Command and Control System (IMMACCS).* "The object-oriented, agent-based command and control program represents the battlefield as a series of graphic objects with specific attributes. For example, a bridge would have its maximum weight capacity listed so a commander would know whether tanks could safely pass over it."[49] The agents perform many of the time-consuming logistics and research tasks. Intelligence agent technology will also monitor data from selected geographic areas of interest within a theater of operations based on reconnaissance and intelligence information down to the squad level. The challenge in this development program is the fusion of differing information feeds and interfaces into multiple systems/sensors to develop a coherent operating picture over a temporal and spatial spectrum using decision support and intelligence agent software.[50] This has obvious applications with NIMA imagery and geospatial data and USIGS/TPED interfaces.

CURRENT NIMA R&D TECHNOLOGIES AND PROGRAMS

NIMA is currently testing and making investments in many new technologies to advance its mission in the fields of multi-INT collaboration, visualization technologies, expert systems in terms of ATR, some basic knowledge management, and cognition and neuroscience work. Although most of the R&D is near term (0-5 years out), there have been on-going activities over the past two to three years in the longer term, advanced technologies areas (10-20 years out). While some of the former are not specifically AI in the pure sense of the term, they all position the agency to leverage off of, and take advantage of, technology that lends itself to AI inclusion. Unfortunately, classical 'Computer Vision' has not had the success over the past to make it feasible for the volume of imagery generated through national technical means (NTM) and certainly not the additional quantity commercial and airborne platforms would generate.[51]

Within the two NIMA strategic goals of transformation of our business model and multi-Intelligence (multi-INT) collaboration, NIMA is working with both the Intelligence Community (IC) and the DoD communities, in a partnership effort. Ongoing efforts within the IC include participation with the IC TestNet in an attempt to encourage intelligence agencies to bring ideas and issues together to work jointly. IC TestNet provides end-to-end operational prototype for *Motion Imagery* and develops a collaborative environment to test and evaluate innovative *Information Technology* to support the IC. The idea is to push the IC into working more like the DoD (DARPA and source labs) into a managed acquisition program. Although most of their R&D is looking at near term (out to 5 years), targeting low risk ventures, they are involved in advanced work in many of the advanced technology areas. There are several ongoing efforts

that could prove beneficial in the near to mid-term. In addition to the IC TestNet program, other partnership activities include: ARDA (IT) community, neuroscience, automatic target detection (ATD), ATR, robotics and machine inspections in industry, repeatable knowledge environment, critical R&D in imagery understanding and handling, data handling, and development of meta data to allow for robotics to take over house keeping chores such as maintenance and updating of files.[52] The following figure shows many of the partnership efforts ongoing with NIMA, where resources are being pooled against common R&D efforts.

FIGURE 3: LEVERAGED RESOURCES AGAINST GEOSPATIAL INTELLIGENCE ADVANCE TECHNOLOGIES [53]

To date, very little proportionately has been programmed in the way of funding for R&D and certainly in long term R&D studies for the IC and NIMA specifically. Current table of authorization (TOA) R&D (JMIP and NFIP funds) includes basic and applied research, demonstrations, experiments and acquisition. However, most of the funds are spent in acquisition and fielding of systems and little in development. These include the enabling technologies of Geospatial Scientist, Computer Scientist, Physical Scientist, Imagery Scientist, and Mathematics as well as the Advanced Technology Developments of Full Spectrum, Geospatial & Geodesy, ATR, Visualization, and DB/KM. NIMA is currently testing and making initial investments into each of those categories, but the problem is the lack of funding. At current funding levels, NIMA can only scratch the surface although they have been engaged at

low levels of research for two to three years in these areas. The NIMA Commission recommended at least 10% of the total NIMA budget should be focused on advanced, higher risk R&D. Currently only about 1-2% of its budget targets these activities.[54]

Also, in regard to AI fields, distinctions become blurred between KNOWLEDGE BASED and PERCEPTION BASED. However there are labs that NIMA is working with (see Figure 3) which include: the National Technology Alliance (NTA) which is looking at near term (0-5 year out) commercial endeavors, off the shelf technologies; the National Information Display Lab (NIDL - hosted by David Sarnoff Research Corp., Princeton, NJ), the National Center Applied Technology (hosted by Autometric/Boeing, Newington, VA) and the National Medial Lab (NML, hosted by 3M Inc., St. Paul, MN). These are looking at overlapping data/images, motion imagery, multi-spectral, symbology, neuroscience, and holographic/3D displays, all of which require more data, greater field of view, HD TV devices and examine literal (real data) versus non-literal (symbology) data.[55]

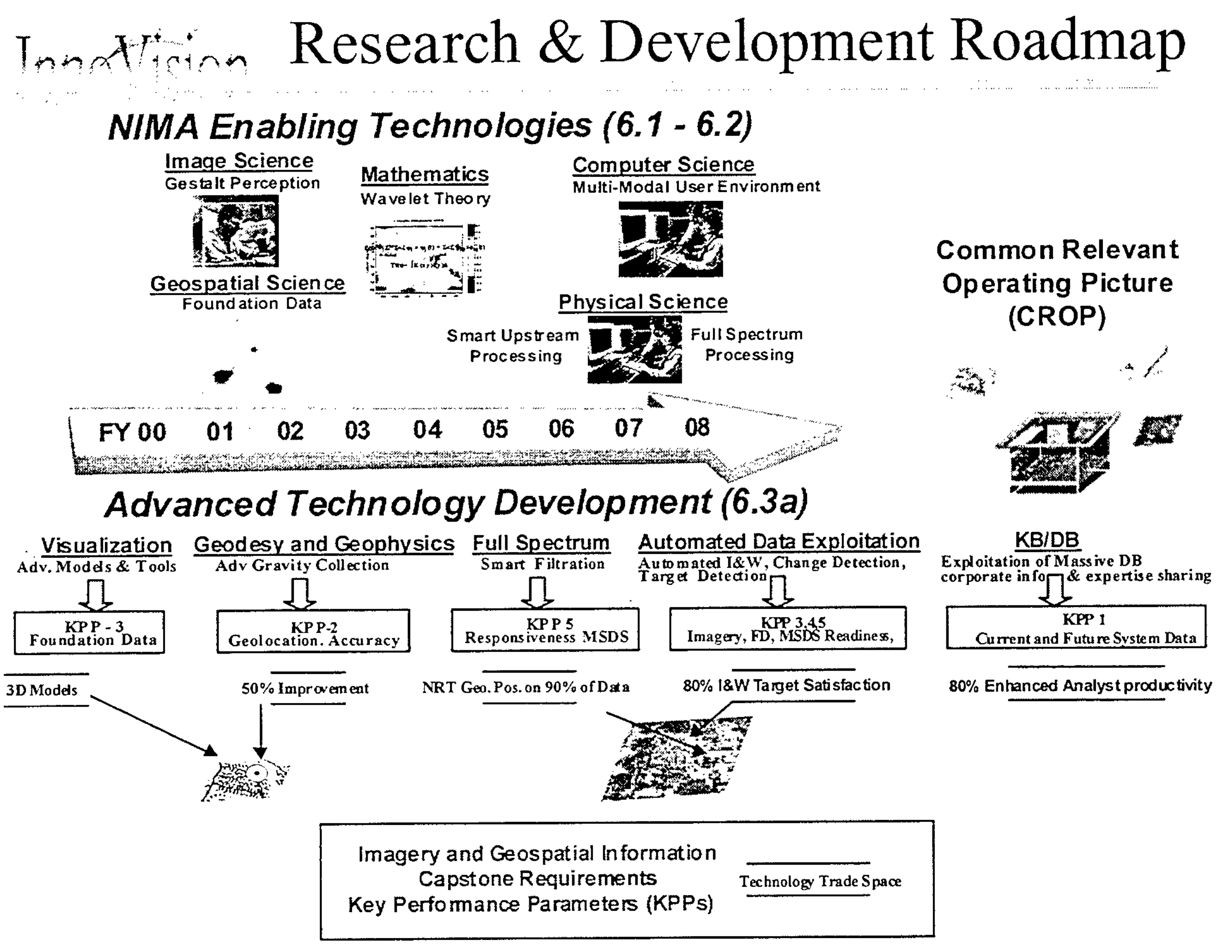

FIGURE 4: NIMA R&D NEAR-MID TERM ROADMAP [56]

NEAR TERM INITIATIVES

NTA Initiatives described in a briefing by Dr. Robert Laurine, DD/InnoVision Directorate include: (1) Open Source Prototype: Prototypes the development of software for use by the government using Open Source Software Development (OSSD) methodologies and evaluates how the government can apply OSSD to existing and future programs. (2) Motion Mining Techniques from UAV Video which develops a new set of automatic motion imagery analysis techniques to detect, track and describe the actions of moving objects (e.g. velocity, acceleration, pattern of motion and interaction with other moving objects); such as people and vehicles, in motion imagery streams. (3) Multi-INT CDA - Enhanced Visualization Modalities: Develops methods to exploit multiple sources of intelligence and to enhance cognitive understanding of disparate data types. This project will incorporate new and diverse data types, display uncertainty, and perform studies targeted to enhance cognitive understanding and visualize network status. (4) Holographic Optical Storage: Develops critical aspects of the high performance holographic polymer recording media prototype.[57]

MID-TO-LONG TERM INITIATIVES

The Advanced Research and Development Division acts as NIMA's proponent for mid-to-long term initiatives. These include all of the aspects discussed above to include: the enabling technologies of Geospatial Scientist, Computer Scientist, Physical Scientist, Imagery Scientist, and Mathematics as well as the Advanced Technology Developments of Full Spectrum, Geospatial & Geodesy, ATR, Visualization, and DB/KM.

Visualization

One advanced R&D project within NIMA focuses on visualization technologies, specifically visualization aspects of 3-D modeling and pattern recognition. Funding shortfalls result in low levels of activity that are externally funded. However, greater investment into this AI field could contribute to visualization of models or patterns by learning from analysts' interactions, filtering information, determining what information to portray and formatting the display. Currently, AI use in pattern recognition algorithms falls into the domain of the geospatial scientist realm.[58]

Geospatial and Geodesy (G&G)

Another initiative underway is the Neuroscience-Enabled Computer Vision (NECV) which will "research Neuroscience approaches that might be applied to Computer Vision Technology. Current Computer Vision technology needs new approaches to meet the demands of automating the imagery and geospatial analysis process to deal with the mass of expected

imagery and other data in order to meet timely relevant analysis needs."[59] Benefits expected from AI to improve visualization for analysis and presentation of information include: (1) more efficient understanding or analysis (time savings); (2) potential identification of information or correlation that could otherwise be missed (reduced errors); (3) Reduction of information overload.[60]

Other Geospatial initiatives underway include the Metric Accuracy Research Project in which NIMA is participating in a joint initiative to promote upstream processing for Future Imagery Architecture (FIA) and beyond. NIMA would like to automate the geospatial functions of point measuring, triangulation, mosaics, and targeting preparation and move these functions to system ground-site locations. This project will support the Upstream Processing initiative by developing new procedures and algorithms to be used in the automation of these activities. One of our challenges is in looking at businesses and off the shelf technologies to encourage a market for the government with phenomenologys straight from the commercial sector. Some examples include ERDAS and ESRI, which are most applicable to geospatial tradecrafts but are digital and are used as data integrators.

Full Spectrum Program

Another project is the Full Spectrum Program (FSP) that will aggressively demonstrate, evaluate, integrate and transition methodologies, strategies and algorithms to the Imagery and Geospatial Community (IGC). The FSP initiative will address data sources collected across the electromagnetic spectrum from shortwave infrared to longwave acoustic.[61]

NIMA has been involved in the advancement of Airborne and Multi-INT technologies/interoperabilities to tie it into the platforms down to the tactical/theater levels. For example, UAV exploitation of video and fielding of exploitation tools or exploited products for motion imagery to the world. These are being worked in conjunction with DARPA, who is taking the lead on UAV projects and image understanding fields.

Knowledge Management/Database

In the area of Knowledge Management, NIMA is involved in a pilot program (Verona KMB) to assist analysts to manage and collaborate on collections of disparate data while focusing on their analytic tasks. This powerful information and knowledge management tool will facilitate the analyst's job of creating, organizing, sharing, and distributing information and knowledge to a wide audience. NIMA analysts should be able to capture and organize many different data types and add amplifying information to the image. It has much utility in the creation and

maintenance of analytical targeting folders for all intelligence customers. [62] This is focused on near term R&D technology to assist imagery and geospatial analysts.

Although DARPA is in the lead on the common relevant operating/interoperating pictures advanced R&D programs over the past 20 years, NIMA is also engaged in these activities. Some have successfully transitioned into operational weapons systems. Within the IC some of their "knowledge management" programs, sponsored by DARPA, have already been placed on Intelink. For instance, Project Genoa, an IC initiated effort, is intended for

> developing tools and a system for collaborative crisis understanding and management for the national security community including Commanders of the Unified Commands. The objectives are to decrease decision cycle time from days to hours, increase number of situations that can be managed simultaneously by an order of magnitude, and reduce number of military deployments. Project Genoa is using and developing advanced information technologies to implement a system of systems which will assist crisis management team members across and up and down the crisis management hierarchy utilizing an infrastructure to accommodate exchange and storage of information and provide an integrating environment for the new technologies as well as for legacy systems. [63]

The infrastructure uses the 'Intranet of Intranets' concept, providing distributed access and multimedia interface capabilities, with mechanisms for managing access, multiple classification levels, and a common data format. Project Genoa utilizes KM technologies for the crisis management team, from the NSC down to the JTFs, posed around 'thinking about thinking' and assistance targeted to policy makers and how to aid them in making decisions and deconflict data. The key enabling technologies are: knowledge discovery of critical information from unstructured multimedia sources; structured argumentation to capture and present reasoning from evidence to conclusion; and a comprehensive corporate memory which will enable comparison of critical information across situation, time, and organization.

ATR/Automatic Change Detection (ACD)

Issues that NIMA needs to grapple with in order to better leverage off of AI technologies include fidelity views, quantifiable data, value knowledge; ACD and ATR – to include pattern recognition, image understanding and expert systems. The challenge lies in reducing the number of false alarm rates and tradeoffs because of the requirement for better resolution, more data, storage (centralized versus decentralized and requirements for deep rich archives) and the fact that much of our historical images are not digitized.[64] A strong partnership with DARPA, who is the lead on many of these efforts, could be most beneficial to long term strategic objectives and resources.

In an effort to leverage off DoD and Intelligence Community activities, NIMA has invested varying amounts of its R&D resources in traditional computer vision approaches focused on automated image exploitation and understanding with varying degrees of success. "As the field of visual neuroscience matures, an opportunity exists to complement, or revolutionize, these current approaches by applying the computational strategies employed by biological systems to this problem domain." [65] Potential areas for exploration include: data extraction across varying acquisition parameters, non-literal imagery, visual attention as a processing strategy, multi-modal sensory integration and inferencing over space and time.[66]

NIMA SHORTFALL AREAS

Major challenges for NIMA leadership will be driven by technology changes. NIMA's business operations are limited today by technology shortfalls as previously discussed. Requirements outstrip our ability to provide timely, mission special data in a usable, standard format to meet varied customer needs. New advances in the fields of Artificial Intelligence may revolutionize such tasks as change detection, broad area search, future feature data collection and propagation by automating many aspects of the tasks. They should also enable NIMA to provide responsive, authoritative national and regional databases and archives. New nano-technology such as MEMS will dramatically minimize many of the resource challenges of today.

Although limited by funding shortfalls, NIMA has had a robust R&D program underway for at least three years and it is getting healthier. One of NIMA's advanced technology emphasis areas is to focus on emerging technologies that are applicable to NIMA in the next 10-15 years. NIMA is not, however, in the strict scientific sense of the definition utilizing AI today, and its investment in AI technologies is very limited and in most cases represents an effort to monitor and track activities in this field. They are exploring 'expert systems' in terms of ATR – and near to mid-term AI technology. DARPA has a very large R&D program, approximately $2 billion a year, and has invested heavily in AI over the years. For NIMA, however, the three fields that could be most useful are Neuroscience, Computational Vision, and Expert Systems (DNA computerizing, parallel computing, evolution from digital to analog computing to facilitate continuous data states). NIMA has begun initial workshops examining Neuroscience enabled Computational Vision advancement contracts. These endeavors will attempt to identify relevant neuroscience-related research and assist NIMA in prioritizing them based on their potential impact to NIMA mission areas and resource requirements in time and labor.[67]

TECHNOLOGY CHALLENGES FOR NIMA

There are significant challenges in the near and mid-term future that NIMA's future planning offices are concerned with such as: (1) Where are the tools to assist the analysts in tracking and managing data? (2) How can we better use Open Source Intelligence (OSINT) and other source data to best pull relevant data for the analysts which is labor intensive today? (3) All of the TPED deferrals have put the government in a most difficult position in terms of economics and timeliness. How do we reconcile this? (4) How do we co-mingle NTM data and imagery with commercial and airborne data and imagery. (5) There is a driving requirement for multi-level security to manage data and cut O&M costs; however the technology, politics and infrastructure are not funded to support this. How can this be overcome? These are some of technology challenges that NIMA's limited R&D funds are focused to solve. What this means is that NIMA as an agency is not free to use those limited dollars to target mid-to-long term R&D technologies, such as AI. Those advanced technologies may in the long run have much more substantial impacts on the agency and the imagery and geospatial professionals throughout the world.

NIMA RISK ASSESSMENT TRADEOFFS

Benefits from these new technologies against cost/risk tradeoffs need to be examined immediately. For AI, we need to make decisions on where to invest funds (research and implementation costs) and send clear messages to industry that is meaningful for them to assist in technology development that benefits both the government and industry. Another challenge to our workforce will be a resistance to computers making analytical decisions against the possibility that critical information has been erroneously identified. If we don't solve both of these problems, we will relinquish our ability to 'shape the future' and will by virtue of that, become irrelevant. We believe that 20 years from now we will have real thinking machines with low false alarms states. However, the government team needs to evaluate whether the 80% solution might be good enough. There is also a major problem with inserting new and emerging technology into the system engineering and acquisition processes which have difficulty in responding to changes in processes and fast innovation; contracts are not often flexible. Therefore, how do we incentivize contractors to partner? Where are the tradeoffs between cost effectiveness for outsourcing and in house production? It may not be cheaper but it may be more responsive. Contracting for infrastructure is eroding. "Modernization is difficult when your costs for personnel are increasing and you have fewer personnel. This is a problem that is

generally faced by other agencies in the IC too. Modernization is difficult while changing to meet current (and highly asymmetric) threats. And the mission is becoming more complex."[68]

CONCLUSIONS AND RECOMMENDATIONS FOR IMAGERY MISSION AREAS:

Given the current state of R&D programs underway in NIMA, critical questions for NIMA leaders include: How well is NIMA doing and where will they be able to bonus off of ongoing efforts? Are they investing wisely in potential major impact efforts – in the short term and long term? Are they poised through R&D programs, funding and sound strategic orientation and planning guidance to take the lead in shaping AI areas that could most benefit the nation in imagery-related issues? An analysis of the aforementioned indicates that there are numerous ongoing programs, with short to mid-term impacts that are available through partnerships with the private sector, the IC, and the DoD (especially DARPA). There is also an assertive advanced technologies effort underway within NIMA, however, a larger percentage of NIMA's budget needs to be invested in longer term technologies and nurtured, especially in the fields of neuroscience, computer vision, and expert systems. NIMA investments to date are somewhat limited and primarily targeted at short to mid-term objectives. [69] They are focusing their efforts by-in-large on 'knowledge management' tools and systems and assisting in some DARPA sponsored image understanding programs. This is a sound strategy in the near term, while the agency is grappling with challenges caused by today's current infrastructure and resource limitations. NIMA is woefully limited on longer term, more risky AI fields that in the long run could have a much greater impact on resource and timeliness savings. While there are programs for R&D, the funding is limited and indeed does not match the strategic objectives described earlier.

Changes need to be made in terms of flexibility and responsiveness in the systems engineering and program management processes to facilitate ease of integration of new technologies. If not modified, NIMA may not be competitive or perhaps relevant as a timely, comprehensive information provider to the full spectrum customers (as documented by the NIMA commission and stated in various DoD guidance documents) in maintaining the information edge. As a minimum, NIMA must relook their current R&D programs and make AI investments in some key areas to increase understanding, and build these into agency strategic objectives targeting higher risk AI technologies.

Recommendations for NIMA and Intelligence Community senior leaders would be to actively review it's R&D investment programs to ensure that enough R&D focus and funding is adequate to ensure that it remains a viable shaping force for the community (end state).

Although the agency is involved in advanced technologies, current funding levels fall well below the recommended levels of the NIMA Commission, thereby severely limiting efforts that will pave the way and minimize the risk for future transformation efforts. AI is a broad and nebulous area. NIMA should continue to discriminate on both near and long term programs, focusing on those efforts that are furthest advanced and have the highest payoff impact, while selectively leveraging the more ambiguous and uncertain technologies through partnership endeavors. An expanded partnership program with private industry and DoD in many of the more long-term technologies would do much to shore-up limited funding profiles while offering the benefit of NIMA's knowledge rich environment in terms of expertise in both imagery and geospatial intelligence.[70] There is also an investment shortfall in the infrastructure to make this work. NIMA R&D efforts now and in the future need to continue to identify and define which areas its must focus efforts and limited resources.

Some AI technologies are available in the near term while others will not bear fruit for several decades. Although a number of AI technologies are promising and may revolutionize the imagery and geospatial intelligence business, they are not ready yet. Therefore, due to limitations in resources and infrastructure, it may be more prudent to closely monitor and be engaged in but NOT LEAD the efforts in some of the horizon technologies such as neuroscience; quantum computing; visualization and cognitive science. Computer strategies by which "natural systems" process the visual world offer new directions for applied research in this area. To this end the NIMA R&D efforts must identify specific neuroscience-related research projects that have the potential to advance imagery-related capabilities. They must also prioritize these based on impact, probability of success, and expected time needs and delivery.

As identified in the NIMA Commission findings and NIMA's Strategic Intent and goals, AI R&D programs are key to the success of the organization and the USIGS community. Further, AI advanced technologies have the potential to revolutionize the imagery and geospatial industry and disciplines. They also have a crucial global role in advancing the use of imagery and geospatial products, data and services over the next 30 years. As the US government's advocate in imagery-related issues and professional development, NIMA's senior leaders must crosswalk the Statement of Strategic Intent's identified goals with the current funding programs to effectively influence and shape that transformation in their effort to remain relevant in their mission areas.

WORD COUNT = 9,349

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